


UNITED STATES PATENT APPLICATION FOR
SYSTEM AND METHOD FOR SOFTWARE COMPONENT
PLUG-IN FRAMEWORK

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[0002] This application claims priority from provisional application "SYSTEM AND METHOD FOR SOFTWARE COMPONENT PLUG-IN FRAMEWORK", Application No. 60/294,467, filed May 30, 2001, and incorporated herein by reference.

Field of the Invention:

[0003] The invention relates generally to object component models and specifically to a system and a method for enabling plugin applications in a framework architecture.

Background of the Invention:

[0004] Today's business environment has become increasingly dependent on electronic commerce or "e-commerce" applications for their day

to day operations. E-commerce applications typically define such enterprise-wide functions as supply chain management purchasing, sales, finance, manufacturing, enterprise resource planning, and data processing. An e-commerce application is typically designed to operate or run on a dedicated computer server or group of servers known collectively as an e-commerce or transaction server. Such server products include the TUXEDO™ product from BEA Systems, Inc., San Jose, California; Weblogic Server™, also from BEA Systems; Commerce Server™ from Microsoft Corporation in Redmond, Washington; and both Avila™ and CRM™ from IBM Corporation, Armonk, New York.

[0005] The key requirements for such servers are that they be proven, reliable, and scalable so as to meet the needs of a growing organization. Some products are also designed with flexibility in mind. Particularly, TUXEDO is geared towards providing a powerful and flexible end-to-end e-commerce solution that can be used to connect and empower all users, while integrating all of a corporations corporate data.

[0006] One of the primary disadvantage of such e-commerce or transaction servers is that they tend to be very large applications in and of themselves. The typical e-commerce server ships as a server application that must be compiled to form an engine or kernel through which client applications may then communicate. Once compiled, very little can be added or modified to the server application, and hence to the system, without requiring a reconfiguration of this kernel.

[0007] **Figure 1** shows a traditional kernel compilation process as it applies to an e-commerce application. As shown therein, the typical e-commerce server may be originally shipped with little or no "personality". As used herein the term "personality" is used to refer to a particular application frontend with which user (client) applications will interact, and include such

personalities as AMS, Jolt and TUXEDO. Personalities communicate with the outside world (i.e., the client applications) via a variety of programming concepts that are hereinafter referred to as "attitudes". Attitudes may include for example, Java, C, C++, Cobol, and OLE (Object Linking and Embedding). Similarly the e-commerce server may ship with little or no extensions, add-on applications that are used by the e-commerce server but are not directly programmed as a client application, and in some cases may not even interact with the outside world. Extensions can be considered as useful utility functions that are used to augment the server's standard features.

[0008] Traditionally, in order to add personalities or extensions the server kernel must be re-configured and recompiled at each step. This necessitates server downtime and greatly increases the risks that errors will be introduced either during the recompile process or during the attempt to get the server running again in the shortest possible time. As shown in Figure 1, switching to a TUXEDO personality, adding a connection module extension, and then adding a security module extension, may take as many as three server downtimes and kernel recompiles. Such compile problems are also encountered when adding routine server application updates and software patches. The traditional server architecture likewise does not lend itself to reuse of Module code when the server kernel is itself replaced. Much time and cost is spent re-writing code for new releases of a server product that does much the same as the last version of the code. Customers who develop custom code to run with or within their server product find their code unusable with server releases of the server product. The overall result is one of redundant coding, expense and wasted time.

Summary of the Invention:

[0009] To address this issue, the inventors have concluded that it would be advantageous to break the existing application transaction server or

e-commerce server into a set of more manageable components. This would also address the following goals:

[0010] Allow commerce and transaction server customers to reuse their client applications with newer or future server products.

5 **[0011]** Eliminate additional steps of porting and recertifying other, related server-based products because of changes to the currently offered server infrastructure.

10 **[0012]** Address the needs of e-commerce server customers who suffer because their server-based products include bugs that have been corrected in the latest version of the server system.

[0013] Reduce the amount of code copied/changed across products through "componentization", and encourage the reuse of software code to minimize redundant coding.

15 **[0014]** Consequently, to address these goals, the inventors propose an e-commerce server architecture wherein a server engine component, referred to herein as an "engine", plays a center role in providing some basic services, and also a plugin mechanism that allows the customization of the engine. This customization may include well-defined interfaces to the engine, and call-outs
20 from the engine. Personalities are provided through plugin modules, including any customizations to the engine's set of extensions.

[0015] Within the server engine, dynamic linking and loading of a plugin module (referred to herein as an interface implementation), and encapsulation of that interface implementation, occurs in such a manner that the interface
25 implementation is totally hidden from the interface user (i.e., the component acting as a client or client application).

[0016] As disclosed herein, the invention provides a plugin framework that may be incorporated into, or as part of, an application server engine to allow

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dynamic customization of the engine interfaces in terms of extending them through plugin modules. These plugin modules are in turn provided by personalities, and engine extensions. Application server engines that may be used with the invention include both e-commerce transaction and application engines. One embodiment of the engine Plugin Framework provides the following features:

A formal plugin module integration model;

A common infrastructure for dynamic loading, linking and unloading of plugin modules;

A common registry mechanism for plugin modules; and

Plugin application programming interfaces (APIs) that act as extensions to the engine provided interfaces

[0017] Both DLL (Dynamic Link Library) and non-DLL types of containers for plugin modules may be supported through various embodiments of the framework architecture. A system incorporating this new architecture can be visualized as a pool of software components interacting with each other through a client-server relationship. As used herein, a software component is considered a "client" when it asks for a service provided by another component, and is considered a "server" when it provides a service being requested by another component. The set of services offered by a component is accessed through a well defined interface. A component can offer multiple sets of either interrelated or not interrelated (i.e. independent from each other) services through corresponding interfaces. To the client, a component thus appears as a set of interfaces. The client does not care how these interfaces are actually implemented by the component. Components as used in this context of this application are thus the implementation provider for a given set of interfaces they support. A component can be removed from an application and replaced with

another component, so long as the new component provides an implementation for the same interface as the old component did.

[0018] When implementing such an interface architecture one of the early design decisions regarding the use of components is to decide on the medium or container for making the component available during run-time. There should be a backing implementation for each interface being invoked by a client. This implementation library can be dynamically linkable, if the requirement is for separating the client from the interface implementation, and dynamically loadable if the requirement is to not load the component until it is actually needed. The library may be another process on the same (i.e. local), node or on a remote node.

Brief Description of the Drawings:

[0019] Figure 1 is an illustration of a prior art server configuration process.

[0020] Figure 2 is a schematic of a framework system architecture in accordance with an embodiment of the invention, illustrating the placement of the engine.

[0021] Figure 3 is a schematic of a component interface in accordance with an embodiment of the invention.

[0022] Figure 4 is a schematic of the engine plugin framework in accordance with an embodiment of the invention.

[0023] Figure 5 is a flowchart of a realization of an interface in accordance with an embodiment of the invention.

[0024] Figure 6 is a schematic of a plugin realization in accordance with an embodiment of the invention.

[0025] Figure 7 is a schematic of a derived plugin or implementation inheritance in accordance with an embodiment of the invention.

[0026] **Figure 8** is a schematic of a fanout type interception in accordance with an embodiment of the invention.

[0027] **Figure 9** is a schematic of a stack type Interception in accordance with an embodiment of the invention.

5 [0028] **Figure 10** is a schematic of a realization of an interface with a fanout implementation in accordance with an embodiment of the invention.

[0029] **Figure 11** is a schematic of a realization of an interface with a stacked implementation in accordance with an embodiment of the invention.

10 [0030] **Figure 12** is a flow diagram of a realization process in accordance with an embodiment of the invention.

[0031] **Figure 13** is a flowchart of interface specification process in accordance with an embodiment of the invention.

Detailed Description:

15 [0032] Included below is a brief glossary of terms, acronyms, and abbreviations which will be useful in understanding the detailed description of the embodiments that follows:

Engine - A collection of common, personality independent services (for example, communications, load balancing, routing, basic security, basic mgmt).

20 As used in the context of this application the term "engine" is synonymous with the word Kernel.

Personality - A programming model support (which includes a mapping to the engine and the environment) for example, API mappings and personality-specific functions.

25 **Attitude** - A programmatic interface for programming model.

Extension - Specialized services for connecting/interoperating with third party products.

Interface - A contract about a set of services between the requestors (clients) and the providers (servers) of the services. This contract specifies a set of functions with the associated syntactical and semantical properties (for example the input/output parameters, or the return value). Services within an interface are usually though not necessarily related.

Interface ID (Iid) - A unique identifier or ID for an interface specification.

Implementation - A set of software modules implementing the services specified by a particular interface.

Implementation ID (ImplID) - A unique identifier or ID for an implementation of an interface. This ID is unique among all of the registered interface implementations associated with a particular interface.

Interface Realization - The process of instantiating an interface implementation and passing a pointer to it for later reference by the client.

Component - A set of software modules bundled together, and providing implementations for a set of interfaces.

Plugin - An implementation for a particular interface.

Plugin Framework (PIF) - An engine plugin framework component as used by the invention to accept plugins.

Registry - A persistent storage data repository for storing PIF related information.

Dynamic-Link Library (DLL) - A component server, or a container for a component. DLLs typically share the same address space as the client application they are linked to. On some platforms (for example UNIX) the container is a shared object in that its text segment can be loaded once and shared among all the processes using it.

Container - A medium for the distribution of plugins. For example, a DLL may act as a container.

Virtual Function Table (Vtable or Vtbl) - An array of pointers for an interface that point to the various implementations of the functions that make up the associated interface.

pVtbl - A pointer to a Vtable

- 5 **Derived Implementation (Composite Plugin, Derived Plugin)** - An interface implementation that inherits the implementations of some of the methods of the interface from other implementations of that interface (in other words it implements or is associated with other implementations of that interface).

Singleton Plugin - A plugin which can only have a single instance.

- 10 **Document Convention** - Throughout the following sections of this document, the following conventions apply within the examples shown:

 [...] indicates an optional item.

- <...> indicates a token which can be replaced by a real value conforming to the syntax specified. The value between < and > is often replaced with a plugin-specific name to retrieve plugin-specific functions.
- 15

- [0033] **Figure 2** shows a schematic of a system architecture in accordance with an embodiment of the invention. As shown in Figure 2, the invention provides a dynamically configurable plugin engine, which in turn is part of a larger plugin framework 200 (hereinafter referred to as a PIF). In one embodiment, the PIF 200 comprises an engine 201, together with various plugin personalities and plugin extensions. These framework components allow a client application to access services in a manner that is transparent to the application invoking the service. Personalities 202 that can be used with the invention include such systems as TUXEDO, Jolt and AMS. These personalities allow a client application 206 to interact with the engine via a set of programming languages or attitudes 208. Attitudes include, for example, the C, OLE and Cobol attitudes offered by the TUXEDO personality. The personalities are
- 20
- 25

plugged-in to the engine as a series of components, as are the services needed by the clients. Specialized plugins, often referred to as extensions 204, may similarly be plugged in to the framework, for example to act as managers or interfaces to a family or group of specialized services 205.

5 **[0034]** As shown, the PIF enables the implementation and support of a component model architecture in which:

[0035] A component is a set of software modules that are bundled together, and which provide implementations for a set of services specified by the corresponding interfaces.

10 **[0036]** An interface is a contract about a set of services between the requestors (clients) and the providers (servers) of the services. This contract specifies a set of functions with the associated syntactical and semantical properties, for example the input/output parameters and the return values, etc. Components utilize a client/server relationship, and communicate with each other through interfaces.

15 **[0037]** With this architecture, the engine 201 can be further visualized as shown in **Figure 3** as a pool of software components interacting with each other through a client-server relationship. A component 212 is considered a client when it invokes a service 220, 224 provided by another component, and a server 214, 215 when it provides a service being invoked by another component. The set of services offered by each server component can be accessed through a well-defined interface 216, 217. A server component can offer multiple sets of services through the corresponding interfaces which may be interrelated or not interrelated (independent from each other).

20 **[0038]** An interface is a binding point between a client component and the server component. The client component need not know how these interfaces are implemented by a server component. In other words, the server component backing the interface is totally transparent to the client component. This means

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that an implementation 221, 222 (a plugin) of an interface 216 can be replaced by other plugins at run-time, without impacting the client application code.

[0039] To a client, an interface may for example be a C language data type structure of which every member is a function pointer pointing to the plugin functions implementing the services defined by the corresponding interface. An interface is thus only a formal specification of a set of services until it (and its corresponding implementations or plugins) is registered and subsequently realized. As such, an interface has to be realized before its services can be invoked. The interface realization process consists of locating the specified implementation, loading it into the caller's address space, and populating an internal table of pointers with the addresses of the plugin functions implementing the services defined by the corresponding interface.

Interface Definition

[0040] One method of defining an interface is to use a standard specification such as the Object Management Group's (hereinafter referred to as OMG) Interface Definition Language (hereinafter referred to as IDL), or a subset of it. However, one can alternatively use any language which supports a "structure", "record", or an equivalent type of data structure with double-indirection support, (e.g. the struct command used in C or C++). The method of actually defining an interface is not necessary for an understanding of the present invention and can be left to the interface developer.

[0041] The interface developer is however expected to provide the following software modules which are then linked by the clients and/or the plugins of that interface prior to run-time:

Header Files: Both the client applications and the plugins use header files to define interfaces, function prototypes of the interface functions, and the

macros for the invocations of various interface functions. These header files are included into the client application and the plugin's source code.

5 **Client stub files:** The client application uses client stub files for invoking the interface functions. A client stub defines an interface as a set of language-specific data types and routines, one for each function (method) that is part of the interface. These client stubs are compiled and linked into the client application.

10 **Plugin skeleton files:** A plugin uses the plugin skeleton files to map client invocations of interface functions to the actual function implementations in the interface implementation (i.e. the plugin).

Interface Identity

15 **[0042]** In one embodiment of the invention, every interface has a name that serves as the compile-time type in the code that uses that interface. These programmatic types are defined in header files provided by the interface developer.

20 **[0043]** The programmatic name for an interface is only a compile-time type used within the application source code. Each interface also has a unique run-time identifier <interface id>, with the following syntax:

<interface id>:= <component name>[/<sub-component name>]/<interface name>

wherein:

25 <component name>:= <an alphabetic character or '_' character><string of alpha-numeric characters & '_' character>;
 <sub_component name>:= <string of alpha-numeric characters & '_'>; and,
 <interface name>:= <string of alpha-numeric characters & '_'>.

[0044] It will be evident to one skilled in the art that the particular variable names and syntaxes given here are for exemplary purposes, and that the invention is not limited to the specific syntax described herein.

5 **[0045]** In accordance with one embodiment, there is one universal namespace for recording <interface id>s in the engine PIF. Each <interface id> is unique within this namespace. In addition to <interface id>, every interface may also have a version associated with it, specified as two numbers, a <major version number> and a <minor version number>. The combination of an
10 <interfaceid> together with a version uniquely identifies a particular version of an interface.

[0046] Versions are used to indicate compatibility among interfaces, and particularly between releases of the same interface. A <major version number> change implies a different interface. Different major versions of an interface are
15 not expected to be compatible with respect to each other. However, the same <major version number>s, but different <minor version number>s of an interface should be compatible in the sense that a version with higher <minor version number> should be downward compatible with the version with lower <minor version number>. Both the <major version number> and the <minor version number> can be given by a numeric string representing a number between 0 and
20 256.

[0047] Each engine's personality and extension has a unique <component name>. An <interface name> should be unique within a component which owns it. The component provider (who may be a third-party vendor or developer) is
25 responsible for assigning <interface name>s, <major version number>s and <minor version number>s to the interfaces which they provide.

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Implementation Identity

[0048] In accordance with an embodiment of the invention every implementation of a supported interface has a unique implementation ID (implid) with respect to the interface it is implementing. This implementation ID has the following syntax:

`<impl id>:= <component name>[/<sub-component name>]/<impl name>`

wherein:

`<component name>:= <an alphabetic character or '_' character><string of alpha-numeric characters & '_'>;`

`<sub_component name>:= <string of alpha-numeric characters & '_'>;`

`<impl name>:= <string of alpha-numeric characters & '_'>; and,`

`<component name>` is the assigned vendor name from a set of reserved vendor IDs.

[0049] There is one universal namespace for recording `<impl id>`s in the engine PIF. Each `<impl id>` is unique within this namespace.

Version Control

[0050] Interface version compatibility is an important issue between an interface requested or invoked by a particular caller, and the interface implementation or plugin which backs or realizes the interface. In accordance with one embodiment of the invention, every interface has a version number that can be specified in terms of major and minor version numbers. A plugin is an implementation of a specific version of an interface. The following rules apply with regard to version compatibility between the interface being realized and the

plugin being considered to back the interface during the realization process (the processing of `_e_pif_realize()` function):

[0051] Each plugin has a run-time knowledge of the version of the interface for which it is providing an implementation. If the major version number of the interface which the caller is attempting to realize and the major version number of the interface which the specified plugin implements are different, then the interface and the plugin are not compatible and in this case the realization of the interface fails.

[0052] If the major version number of the interface the caller is attempting to realize, and the major version number of the interface which the plugin specified implements are the same, then the following subset of rules apply:

[0053] An interface with a higher minor version number is downward compatible (in terms of functionality, and function signatures) with interfaces with lower minor version number and identical `<interface id>`.

[0054] An interface with a lower minor version number and identical `<interface id>` is a subset of an interface with a higher minor version number.

[0055] During the realization process, the backing plugin (i.e., the one which is realizing the interface) must have a minor version number which is equal or higher than the minor version number of the interface being realized.

Otherwise, the interface and the plugin are not compatible.

[0056] The Vtbl returned by a plugin implementing an interface with a higher minor version number is allowed to grow only in a downward compatible way in terms of both size and content with the Vtbl of a plugin implementing the same interface, but with a lower minor version number. The term Vtbl used herein takes its common meaning and is a term known to one skilled in the art.

[0057] The rules described above are given to illustrate a particular embodiment of the invention and particularly version numbers used within that

embodiment. It will be evident to one skilled in the art that other rules can be substituted for or added to those shown above while remaining within the spirit and scope of the invention.

5 **Plugin Profiles**

[0058] PIF profiles provide a way of associating a PIF client (the caller of a PIF external interface function, whether it is an application process or a system process) with a set of PIF related attributes during run-time. A PIF client may want to use its own implementation for a specific interface or it may want to realize a different implementation.

[0059] PIF profiles are identified by unique profile identifiers called <profile id>s. The syntax of a <profile id> is specified below.

<profile id>:= <a character string consists of alpha numeric characters and _ character>.

[0060] There is one universal namespace for <profile id>s in the engine PIF. Each <profile id> is unique in this namespace. The PIF can be configured to always search the profile <profile id> specified by an **EV_PIF_PROFILE** environment variable in <interface id> or <impl id>, before it searches for the default system-wide profile. A group of clients may be associated with the same profile and consequently refer to the same set of interface/implementation object attributes. A PIF client may be associated with an existing PIF profile by setting the **EV_PIF_PROFILE** environment variable to the desired <profile id>.

25 **PIF Registry**

[0061] The PIF needs to locate the necessary plugin container, which can be a DLL (which contains the specified plugin), in order to load it into the registry

Therefore it needs to know its image path and also other attributes about the interfaces and the interface implementations it is dealing with. To accomplish this, an embodiment of the invention uses a persistent storage based data repository for storing this kind of information. The PIF does not require a particular structuring for the persistent storage based plugin related information. Instead, the PIF describes this plugin information and specifies a set of command utilities for registering and unregistering plugins and for querying and/or updating the stored plugin information. Within this document, the data repository that is used for storing PIF related information is referred to as the "registry". In the registry, interfaces and interface implementations are identified by <interface id>s and <impl id>s, respectively.

[0062] Both the interface, and the implementations backing it, have an associated set of attributes. In addition, an implementation is always associated with the interface it implements. Given a particular interface, there may be multiple implementations for that interface. An interface identifier <interface id> is an attribute of an interface implementation, identifying the interface this particular interface implementation implements. An implementation identifier <impl id> is an attribute of an interface it is associated with the implementation.

[0063] In object-oriented terminology, the registry may be considered a persistent store for PIF related objects and their associated attributes. These PIF related objects and their attributes are described in table 1, table 2 and table 3. Table 1 lists some interface objects, table 2 implementation objects, and table 3 profile objects. It will be evident to one skilled in the art that other objects can be stored within the registry to supplement or replace those shown, while remaining within the spirit and scope of the invention.

Interface Object		
Attribute	Value of Attribute	Description
Interface Id	<interface id>	Interface id of an interface specification
Major Version Number	<major version number>	Major version number of the interface.
Minor Version Number	<minor version number>	Minor version number of the interface.
Selector	<selector>	A string of alpha numeric characters & '_'. It is unique among the <selector>s associated with an interface object. Multiple <selector>s can be defined for an interface object.
<selector>	<impl id>	Used for aliasing a plugin implementing the associated interface object. A <selector> is independent of the version of the interface.
Default Impl	<impl id>	Implementation id of the default interface implementation, per major version of an interface object.

Table 1

Implementation Object		
Attribute	Value of Attribute	Description
ImplId	<impl id>	Implementation id of an interface implementation.
Image Path	<Container path name>	Path name of the container or DLL containing the associated interface implementation.
Entry Func	<_ec_pif_instantiate>	Name of instantiation function of the interface implementation object.
Impl Major Version	<major version number>	Major version number of the implementation object that is different than the major version number of an interface object.
Impl Minor Version	<minor version number>	Minor version number of the implementation object that is different than the minor version number of an interface object.
Params	<string>	A string of characters to be passed to implementation object's instantiation function if defined. Multiple Params attribute can be defined for an implementation object.
Inherits From	<impl id>	<impl id> of the interface implementation this implementation inherits from.
Interception Type	STACK or Fanout	This attribute specifies the type of interceptor sequence specified with the corresponding InterceptionSequence attribute of the implementation object.
Interception Seq	<impl id>, ..., <impl id>	Ordered sequence of implementation ids of the interface implementations whose methods are invoked in the specified order (left-to-right). The interface implementations specified are all associated with the same interface.

Table 2

Profile Object		
Attribute	Value of Attribute	Description
Profile Id	<profile id>	A unique (within the registry) profile id
A set of Interface Objects		
A set of Implementation Objects		

Table 3

Plugin Registration

[0064] Before an interface implementation can be used (i.e., before it can be realized), it must be installed in the system and registered within the registry. Unregistration and/or uninstallation of the interface implementation is required to later remove all the relevant information from the registry. To accomplish these tasks, the PIF provides the following command utilities:

epifreg () for registering a plugin.

epifunreg () for unregistering a plugin.

epifregedt () for editing registry based PIF related information.

[0065] The functions epifreg, epifunreg, epifregedt and the other functions described below, are given these function names for purposes of illustration. It will be evident to one skilled in the art that the invention is not limited to using the specific functions described herein.

Dynamically Loadable Library (DLL)

[0066] In one embodiment of the invention a dynamically loadable library (DLL) is used as the component server or container. Implementations of the interfaces (plugins) are contained inside DLLs. In accordance with one embodiment a DLL may contain only one plugin although their embodiments may

support multiple plugin DLL's. A plugin may not span over multiple DLLs. A DLL may contain multiple plugins which may or may not be for the same interface. A DLL may contain a derived plugin, which implements only a subset of the functions which make up the corresponding interface, and which inherits the implementation of the remaining functions of the interface from another plugin.

[0067] The PIF provides the following functions or services for loading and unloading a DLL to and from the caller's address space, and for getting the address of a function in a loaded DLL:

_e_dl_load is used for loading an executable module into the address space of the calling process.

_e_dl_unload is used for unloading a dynamically loadable library (DLL) module from the calling process' address space. This function also decrements a reference count associated with the specified library.

_e_dl_getfuncaddr is used for getting the address of an exported dynamically loadable library (DLL) function given a function name.

_e_dl_addrref is used for incrementing the reference count associated with a DLL.

[0068] These functions can be provided as a library tailored to each desired or supported personality. For example, for use with TUXEDO, the functions may be provided through a TUXEDO standard **libgp** library.

Plugin Framework External Interfaces

[0069] The PIF external interface comprises the following functions:

_e_pif_realize() for realizing an interface and instantiating a plugin.

_e_pif_dupref() for incrementing the reference count associated with an instance of a plugin (which can be used for lifetime control), or for duplicating a plugin instance.

_e_pif_release() for decrementing the reference count associated with an instance of a plugin used for lifetime control.

_e_pif_getinfo() for getting information about a plugin.

_e_pif_iscompatible() for version compatibility checking.

5 **_e_pif_interception_seq()** for getting the ordered sequence of interface pointers of the plugin instances in the fanout type interception sequence.

_e_pif_this() for getting the address of the private data.

Realization of An Interface

10 **[0070]** **Figure 4** illustrates the flow of function invocation sequences during the interface realization process. Until it is realized, an interface is merely a specification of a set of function signatures with the associated behavioral semantics. In one embodiment, a number of implementations 238 can be stored in a container 240. In this example, a DLL file is used although other types of containers can serve this function. A client application 230 is used to register (and later to optionally unregister) these implementations within a framework registry 234. The registration process is accomplished by a series of routines epifreg, epifunreg, and epifregedt, described above. The names given herein for routines or functions are illustrative and are not required in all embodiments of the invention, but instead may be substituted or replaced with equivalent mechanisms and routines.

15 **[0071]** Following the registration process, the registry thus contains a list of all current implementations. When a client application makes a request to use an implementation they must realize the interface. This is performed through an
20 **_e_pif_realize** routine. Other routines, such as **_e_pif_getinfo** allow the client application to get additional information about the interface. A call to realize the interface is passed to a kernel portability layer 242. The kernel portability layer allows the PIF 200 itself to be independent of the operating system layer 246.

The PIF translates the realize request from the client into a series of function requests 244 to the kernel portability layer to load the appropriate implementation container. The PIF also issues requests 248 to the appropriate container to instantiate a particular implementation (and later passes requests 250 to release that implementation).

[0072] For an interface to be useful, an interface has to have a language binding, an implementation, and a well defined set of rules for interaction between the client and the implementation of the interface. This set of rules comprises the "interface realization protocol." The interface realization protocol encompasses rules governing client invocation, virtual function tables, plugin instantiation and reference counting. In accordance with an embodiment of the invention, the client of any particular interface must have a handle (pointer) to a newly created instantiation of a plugin backing the interface before it can invoke any of the functions of the interface. It acquires this handle for the interface by invoking the **_e_pif_realize** function, an example of which is shown in listing 1 (TM32U is used to refer to an unsigned integer variable, other variable types can be used):

```

_e_pif_realize ( IN    _TCADEF,
20  IN    const char *pIID,          /* pointer to interface id */
      const char *pImplId,        /* pointer to implementation id */
  IN    const struct _e_pif_iversion *version, /* interface version */
  IN    const void *data, /* data passed to plugin from caller */
  IN    long datalen,          /* size of buffer data points to */
25  OUT   void **pI, /* interface pointer */
  IN    TM32U          flags      /* flags */
)

```

Listing 1

[0073] The pointer to the implementation id (implementation id pointer), hereinafter referred to as **pImplId** can be specified as either an <impl id> or a <selector>, or NULL. If **pImplId** is specified as NULL, then the <impl id> of the

default implementation defined in the registry database (DefaultImpl attribute) is used instead. This default implementation is searched according to the search rules associated with the registry database, such as, for example, the first client's (caller's) profile and then the system-wide profile for the interface ids.

5 **[0074]** **Figure 5** shows a flowchart of a method used to read an implementation into a client's memory space. As shown in Figure 5, in step 252 a set of framework interfaces is defined. In step 253 the client application is developed or otherwise instructed to use a particular interface defined within the framework. In step 254 the client application makes a request to actually use the
10 interface within the plugin framework (PIF). A call is made to realize the interface (step 255). This results in the client receiving a pointer to the desired implementation (step 256), which it then uses in step 257 to locate the implementation, and to retrieve the implementation into local memory.

15 **[0075]** The interface realization in this example involves only a single implementation (with no inheritance) and is further described in **Figure 6**. In Figure 6, a calling application (caller) 260 uses the PIF 262 to realize an implementation plugin A 264. The dashed lines in the Figure indicate the invocation sequence and the handles returned to various components during the realization of an interface. The solid lines in Figure 6 indicate the relationships
20 among the data structures involved in interface realization. The caller 260 issues a request 266 to the PIF 262 to realize an interface. The PIF uses this request information and the information stored in the registry to send an instantiate request 268 to a plugin A 264. The PIF uses the information stored within the plugins Vtbl 270, private data store 274, and per-instance data structure 272, to
25 create a proxy Vtbl 276. A pointer 278 to the proxy Vtbl is then returned to the caller. The caller uses this pointer to thereafter communicate 280 with the interface and the implementation. Each of these processes is described in further detail below.

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5 [0076] As shown in Figure 6, the handle returned (ip) is a pointer to a data structure in memory, called a Proxy Virtual Function Table (Proxy Vtbl). In one embodiment, the Virtual Function Table (Vtbl) is a C struct of function pointers pointing to the actual functions comprising the implementation for the interface being realized. Every plugin is required to maintain (e.g. allocating a memory block and populating it) its own Vtbl. Plugins are also responsible for managing per instance private data and plugin-wide **struct _e_pif_plugin_info** data structure. The PIF is responsible for presenting to a client a realized interface as a C struct, of which the members are pointers to functions implementing the function signatures which the interface specifies.

10 [0077] As part of interface realization process, the PIF loads the container or DLL containing the target plugin for backing the interface, and then invokes `<_ec_pif_instantiate>()` function of the plugin, if it is available and registered. Otherwise, it invokes a DLL-wide **_ec_pif_instantiate()** function to instantiate an instance of the plugin. Both **_ec_pif_instantiate()** and `<_ec_pif_instantiate>()` functions have the same function signature. Given a pointer to an `<interface id>` and a pointer to an `<impl id>`, they instantiate a plugin and return three handles: the address of the plugin's Vtbl; the address of the plugin instance specific private data; and the address of the plugin's **_e_pif_plugin_info** structure.

15 20 [0078] The **_e_pif_plugin_info** structure contains information relevant to the implementation of the interface. In particular, an **EF_PIF_SINGLETON** flag indicates to the PIF that the implementation is a "singleton". When a singleton implementation is instantiated, new calls to instantiate the implementation result in a reference to the first plugin instance. The PIF may use this singleton indication to optimize reference handling for other **_e_pif_realize()** calls to this implementation (since the PIF is not required to call the **_ec_pif_instantiate()** function). If a particular implementation turns off this indication, then the PIF will

25

always call the `_ec_pif_instantiate()` function every time the client realizes the implementation. Realization of a non-singleton plugin always results in a new plugin instance.

5 **Plugin Lifetimes**

[0079] The term Interface Lifetime Control is used herein to refer to the mechanism and the set of rules which are used to determine when to unload the container or DLL which contains the implementations of the interfaces that are currently in use. One of the goals of the invention is to make the caller or client immune to replacement of an interface's current implementation by another implementation. To the client, a component is the interfaces it supports. In most cases, the client does not know anything about the actual implementation of the interface provided by the component. Thus, the client can not directly control the lifetime of a DLL since different parts of a program may refer to different interfaces and/or multiple instantiations of the same interface supported by the DLL. In practice, a client will not want to unload the DLL when it is finished with one interface, but still using another interface. Determining when to release a DLL gets increasingly complicated with an increase in the complexity of the client application program. The PIF can be used to manage this lifecycle.

[0080] To accomplish this, the PIF provides two functions, namely, `_e_pif_dupref()` and `_e_pif_release()` which can be invoked by PIF's clients for plugin lifetime control purposes. The PIF maintains a reference count for each plugin instance. When a client gets an interface pointer, the corresponding reference count is incremented by calling the `_e_pif_dupref()` function of the interface. When the client is finished using an interface, the reference count is decremented by calling the `_e_pif_release()` function of the interface. When all the reference counts of all the interfaces supported by a DLL falls to 0, the DLL is unloaded from memory.

[0081] In addition to these two functions provided by the PIF, plugins may provide an implementation of the `_ec_pif_destroy()` function. The PIF invokes this function when the reference count for a plugin falls to 0. Effective use of a reference counting scheme imposes some rules on the parties involved, which are as follows:

1. Functions that return interface pointers should always call `_e_pif_dupref()` with the interface pointer before returning the interface pointer.
2. When the client is finished with an interface (such as not using the interface pointer anymore), it should call `_e_pif_release()` with that interface.
3. Functions should call `_e_pif_dupref()` whenever an interface pointer is assigned to another interface pointer.
4. Interface pointers with nested lifetimes (e.g. the lifetime of one interface pointer is contained within the lifetime of another interface pointer) do not need to be reference counted. However, interface pointers with overlapped lifetimes, must both be reference counted.
5. Any function that returns a new interface pointer in a function parameter set by the callee should call `_e_pif_dupref()` with the new interface pointer.
6. An interface pointer passed into a function in a function parameter that may possess value to a function does not require an `_e_pif_dupref()` and `_e_pif_release()` because the function is already nested inside the lifetime of the caller.
7. Local copies of interface pointers that are known to exist only for the lifetime of a function do not require `_e_pif_dupref()` and `_e_pif_release()` pairs.
8. If an interface pointer is stored in a global or member variable, the client should call `_e_pif_dupref()` with the interface pointer before passing it to another function.
9. Whenever in doubt, `_e_pif_dupref()` and `_e_pif_release()` pairs should be added.

[0082] Every implementation of an interface should provide the `_ec_pif_copy()` function in support of the PIF's `_e_pif_dupref()` function. In one embodiment when the `_e_pif_dupref()` function is called with a `EF_PIF_DEEP_COPY` flag and the plugin is not a singleton, the PIF calls the plugin's `_ec_pif_copy()` function to obtain a copy of the private data of the plugin instance. Then, the PIF creates a new instance of the implementation.

[0083] Each plugin container (DLL) also provides a `_ec_pif_instantiate()` for instantiating a plugin which the container contains. This function is invoked by the PIF during realization of an interface if the selected plugin does not provide its own `<_ec_pif_instantiate>()` function and does not set the value of its registry attribute `EntryFunc` to the name of its `<_ec_pif_instantiate>()` function.

[0084] When calling member functions, the caller must include the interface pointer to the plugin instance (which is returned from the corresponding `_e_pif_realize()` function) as the first parameter. In accordance with an embodiment of the invention every plugin of a defined interface is required to obey the following rules :

1. It should maintain a static Vtbl populated by the addresses of its functions implementing the function signatures of the interface the plugin implements. The address of this Vtbl is the address returned by the corresponding `_ec_pif_instantiate()` function or plugin specific `<_ec_pif_instantiate>()` function and will be the address passed to `_e_pif_this()` function as the second argument.
2. It should provide implementations for the following functions:
 - `_ec_pif_destroy()` to destroy the plugin instance.
 - `_ec_pif_copy()` to create a duplicate copy of a specified plugin instance.
3. It should maintain a static memory block populated with the plugin specific information.
4. It may optionally provide a function which is invoked by the PIF to instantiate it. The `EntryFunc` attribute of a plugin is set to the name of this

function. The function signature of this function is identical to that of `_ec_pif_instantiate()` except for the name.

5. Plugin functions implementing corresponding interface functions should receive an interface pointer as their first parameter.

5 6. Plugins are responsible to manage their private data where applicable.

7. All the functions of a plugin invoked in the context of a plugin instance may access the same private data area, which is per-instance of a plugin and is not per-function of a plugin, or per-function of a plugin instance.

8. Plugins using private data may access their private data by invoking `_e_pif_this()` function.

Implementation Inheritance

[0085] The PIF allows one interface implementation to inherit the implementation of a subset of interface methods or functions from another interface implementation within the same interface. This inheritance relationship between any two interface implementations of the same interface is specified with an InheritsFrom attribute. The InheritsFrom attribute is an attribute of the plugin which is inheriting and the value of this attribute identifies the interface implementation inherited from. This attribute takes an <impl id> as its value.

20 [0086] The PIF may support single or multiple inheritance. With single inheritance the implementation that is inherited from may in turn inherit from another interface implementation by setting its InheritsFrom attribute to the <impl id> of the plugin it is inheriting from.

[0087] The memory layout of the interface realization through implementation inheritance is described in **Figure 7**. As shown in Figure 7, dashed lines indicate the invocation sequence and the handles returned to various components during the realization of an interface; solid lines indicate the relationships among the data structures involved in interface realization. As

before, a calling client 260 issues a request 266 to the PIF 262 to realize an interface. The PIF uses the information in the request and in the registry to send an instantiate request 268 to plugin A 264. Information from plugin A's vtable 270, private data store 274, and per-instance data structure 272 is used to populate part of the proxy vtable 276. This allows plugin A to fulfill a subset of the interface functions. The remaining interface functions are provided by a derived plugin B 284. Derived plugin B provides information from its Vtbl 290, private data store 294, and per-instance data structure 292, to populate the remaining functions in the proxy Vtbl. The caller then uses a pointer 278, as before, to communicate with the interface and the backing implementation via the proxy vtable. The following rules apply to the interface realization process:

[0088] All of the plugins involved in the implementation inheritance or in the inheritance sequence should have a major version number that is equal to that of the interface being realized.

[0089] At least one of the plugins involved in the implementation inheritance should have a minor version number that is equal to or higher than, that of the interface being realized.

[0090] The minor version number of the derived plugin (the final output of implementation inheritance process) is that of the plugin with the highest minor version number among all the plugins involved in the implementation inheritance process.

[0091] If any of the above rules are violated during the inheritance process, then the interface realization process may fail and an EE_PIF_VERSION_MISMATCH error value returned to the caller of _e_pif_realize().

[0092] The Proxy Vtbl should not have NULL or invalid address valued entries.

[0093] The specific rules described above are give for purposes of illustrating a specific embodiment of the invention, and to demonstrate the flexibility of the PIF system. These rules need not be implemented in whole or in part in order to operate the invention, and other rules may be substituted for those described above, while remaining within the spirit and scope of the invention.

[0094] The PIF may also support interface inheritance the process of which operates similarly to that shown for plugin inheritance.

Interceptors

[0095] Interceptors provide a flexible means of adding services to a system. They allow the binding between the client and the target objects to be extended and specialized to reflect the mutual requirements of both. Interceptors can be logically thought of as being interposed in the invocation and response code paths between the client application making a request and the implementation of the object on which the request is made. As such, interceptors are the functions or methods of the configured interface implementations or plugins which provide the services being interposed.

[0096] In one embodiment of the invention the engine supports two types of interceptors: Fanout type interceptors and Stack type interceptors. Interceptors are specified with a pair of attributes, namely, `InterceptionType` and `InterceptionSeq`.. These attributes are associated with an interface implementation `<impl id>`. The `InterceptionType` attribute specifies the type of interception (either **Fanout** or **STACK**) while the `InterceptionSeq` attribute defines an interception sequence.

[0097] An `InterceptionSeq` attribute specifies the intercepting plugins and their interception order. In one embodiment its value is a comma separated ordered set of `<impl id>`s, describing the order of the plugins whose methods are invoked in the order specified when the functions of the corresponding interface

are called. Wherever a verb of the interface is referred to in a code path, the corresponding functions of the interface implementations specified in the data field of InterceptionSeq value are invoked in the order specified.

5 Fanout Type Interceptors

[0098] Fanout type interception is illustrated in **Figure 8**. As depicted in Figure 8, Fanout type interception can be implemented totally independently from the PIF. The PIF does not need to be aware of its existence and as far as the PIF is concerned, the interception sequence is no more than a group of plugins comprising the interception sequence specified with the InterceptionSeq attribute. In this approach however, the Fanout plugin needs to know how to access the registry to get the value of the corresponding InterceptionSeq attribute. This can be accomplished by exposing the registry application programming interface (API) or by using the PIF's help to support access by the Fanout type interceptors.

[0099] In one embodiment the PIF may provide the necessary support with `_ec_pif_instantiate()` and `_e_pif_interception_seq()` functions. Referring again to Figure 8, in this model of interception, the calling client or caller 302 invokes the methods of plugin A 304, but is not aware of the intercepting plugins 306, 308, 310, 312. During the instantiation of plugin A, the intercepting plugins as specified by the InterceptionSeq attribute of plugin A are also instantiated by the PIF and the sequence of ordered addresses of these instances of the intercepting plugins is passed to plugin A via `_ec_pif_instantiate()`. Subsequent method invocations by the client or interface caller results in invocation of the corresponding methods of intercepting plugins in the order specified by the InterceptionSeq attribute.

[0100] The key characteristics of this interception model can be specified as follows:

Given that client invokes method X of plugin A (denoted as 303 in Figure 8) method X of plugin A invokes method Xs of the intercepting plugins in the Fanout order specified by the InterceptionSeq attribute of plugin A as follows:

5 method X of plugin 1 is invoked 314
 method X of plugin 1 returns 316
 method X of plugin 2 is invoked 318
 method X of plugin 2 returns 320
 method X of plugin 3 is invoked 322
10 method X of plugin 3 returns 324

 method X of plugin n is invoked 326
 method X of plugin n returns 328
 and finally, method X of plugin A returns to the caller 329.

- 15 **[0101]** The methods of intercepting plugins return success or failure on function returns.
- [0102]** The sequenced method invocation stops with the first method returning failure condition, and the status returned to the client.
- 20 **[0103]** All of the plugins involved in the interception implement the same interface, i.e., their corresponding methods have the same signatures.
- [0104]** Multiple occurrences of the same plugin are not allowed in an interception sequence.
- [0105]** No intercepting plugin in a Fanout type interception sequence is
25 allowed to be a Fanout type plugin or a stack-type plugin.
- [0106]** A plugin is not allowed to be both a Fanout type plugin and a stack-type plugin.

[0107] FanOut type plugins are not allowed to be derived (i.e., inheriting) plugins.

[0108] The specific rules described above are give for purposes of illustrating a specific embodiment of the invention, and to demonstrate the flexibility of the PIF system. These rules need not be implemented in whole or in part in order to operate the invention, and other rules may be substituted for those described above, while remaining within the spirit and scope of the invention.

Stack Type Interceptors

[0109] Stack type interception is illustrated in **Figure 9**. In the Stack type interception model shown in Figure 9, the client 332 invokes the methods of plugin A 334, but is not aware of the intercepting plugins 336, 338, 340. The PIF is responsible for loading and instantiating the intercepting plugins, as specified by the relevant InterceptionSeq attribute, in addition to plugin A during interface realization, and for building and maintaining the interception sequence.

[0110] Subsequent invocations of methods of plugin A by the client (interface caller) result in invocations of the corresponding methods of intercepting plugins in the order specified by the InterceptionSeq attribute. During the realization of an interface involving stack type interception sequence, the PIF passes the interface pointer to the next plugin in the interception sequence via <_ec_pif_instantiate>() function of each plugin in the sequence.

[0111] The key characteristics of this interception model can be specified as follows:

Given that client invokes method X of plugin A (shown as 333 in Figure 9), method Xs of the intercepting plugins are invoked in the order specified by the InterceptionSeq attribute of plugin A as follows:

method X of plugin A invokes method X of plugin 1 342

method X of plugin 1 invokes method X of plugin 2 344

.....

method X of plugin n-1 invokes method X of plugin n 346

method X of plugin n returns 348

method X of plugin n-1 returns

5

.....

method X of plugin 2 returns 350

method X of plugin 1 returns 352

method X of plugin A returns to the caller 355.

10

[0112] As with the Fanout type interceptors, with Stack interceptors, all of the plugins involved in the interception implement the same interface, i.e., their corresponding methods have the same signatures.

[0113] Sequenced method invocation stops with the first method returning failure condition, and this status returned to the client.

15

[0114] All the plugins involved in a stack-type interception sequence are required to be stack-type plugins except that the last intercepting plugin in the sequence is allowed to be a non-intercepting (neither Fanout type nor Stack-type) plugin.

20

[0115] Multiple occurrences of the same plugin are not allowed in an interception sequence.

[0116] A plugin is not allowed to be both a Fanout type plugin and a Stack-type (Stack-aware) plugin.

[0117] Stack-type plugins are not allowed to be derived (i.e., inheriting) plugins.

25

[0118] The specific rules described above are give for purposes of illustrating a specific embodiment of the invention, and to demonstrate the flexibility of the PIF system. These rules need not be implemented in whole or in

part in order to operate the invention, and other rules may be substituted for those described above, while remaining within the spirit and scope of the invention.

Process Threading

- 5 **[0119]** In one embodiment of the invention, the PIF can serialize calls to a particular implementation's `_ec_pif_instantiate()`, `_ec_pif_copy()`, and `_ec_pif_destroy()` function, and make use of separate processing threads. This can contribute greatly to the overall performance of the system.

10 Interface Function Utilities

[0120] The following section illustrates various functions that are used with the PIF system to register implementations and to realize interfaces. It will be evident to one skilled in the art that additional or alternative functions can be used within the spirit and scope of the invention.

15

`_e_dl_load`

[0121] The `_e_dl_load` function maps the specified executable module into the address space of the calling process.

20

```
_e_dl_load (IN _TCADEF, IN const char *dllpath, /* address of
                                         filename of executable module */
OUT ET_DL_HANDLE *dllhandle, /* DLL handle */
IN TM32U          flags      /* flags */
) ;
```

25

wherein **`_TCADEF`** is the optional ANSI definition of the engine context (typically used only for Tuscedo implementations).

`dllpath` is a pointer to a null-terminated string that names the DLL file. If the string specifies a path but the file does not exist in the specified directory, the

function fails. If the string does not specify a full path name, the function uses a standard search strategy to find the file.

dllhandle is the DLL handle to be used in subsequent **_e_dl_unload** and **_e_dl_getfuncaddr** functions.

5

_e_dl_unload

The **_e_dl_unload** function unloads a DLL:

```
10  _e_dl_unload(IN _TCADEF, IN ET_DL_HANDLE dllhandle, /* handle to
                                     loaded library module */
               IN TM32U      flags /* flags */
               ) ;
```

15 **[0122]** The **_e_dl_unload** function unloads the specified library from the address space of the calling process. After this call, the specified handle is no longer valid, wherein:

dllhandle identifies the loaded library module. The **_e_dl_load** function returns this handle.

20

_e_dl_getfuncaddr

The **_e_dl_getfuncaddr** function returns the address of the specified exported dynamic-link library (DLL) function:

```
25  _e_dl_getfuncaddr(IN _TCADEF, IN ET_DL_HANDLE dllhandle, /* handle
                                     to loaded library module */
                    IN  const char *pFuncName, /* name of function */
                    OUT void **pfa, /* pointer to pointer to func address */
                    IN  TM32Uflags /* flags */
30  ) ;
```

[0123] The **_e_dl_getfuncaddr** function returns the address of the specified exported dynamically loadable library (DLL) function in **pfa**, wherein:

_TCADEF is The ANSI definition of the engine context as before.

dllhandle identifies the DLL module that contains the function. The **_e_dl_load** function returns this handle.

pFuncName points to a null-terminated string containing the function name.

Pfa is Pointer to pointer to func address.

_e_dl_addrf

The **_e_dl_addrf** function increments the reference count associated with a loaded DLL:

```
_e_dl_addrf ( IN      _TCADEF,  
IN ET_DL_HANDLE  dllhandle,      /* DLL handle */  
IN TM32U        flags           /* flags */  
) ;
```

[0124] The **_e_dl_addrf** increments the reference count of the DLL specified by **dllhandle**. It should be called for every new copy of a pointer to an instant of a plugin, wherein:

dllhandle identifies the DLL module that contains the function. The **_e_dl_load** function returns this handle.

_ec_pif_instantiate

The **_ec_pif_instantiate** function instantiates a plugin:

```
_ec_pif_instantiate (IN _TCADEF,  
IN const char *pIID,      /* pointer to interface id */  
IN const char *pImplId,   /* pointer to implementation id */  
IN const struct _e_pif_iversion *version, /*interface version */
```

IN const struct _e_pif_data *pData, /* data passed from caller
and/or registry */
IN const struct _e_pif_interception_data *pInterceptionData,
/* interception data */
5 INOUT struct _e_pif_instance_handles *pI, /* instance cookies */
IN TM32U flags /* flags */
);

[0125] The **_ec_pif_instantiate()** function is a container-wide, default
10 plugin instance instantiate function (<_ec_pif_instantiate>()), invoked by the
Plugin Framework (PIF) during the realization of an interface (i.e. as a result of
a client invoking **_e_pif_realize()**). It is implemented by a plugin implementer and
is invoked only if plugin specific instantiate function is not available. If a plugin
specific <_ec_pif_instantiate>() function is provided, then this function is invoked
15 rather than the DLL-wide **_ec_pif_instantiate()** function. The plugin specific
<_ec_pif_instantiate>() function has the same function signature as that of
_ec_pif_instantiate() function, wherein:

pIid is a pointer to the interface identifier.
pimplid is a pointer to the implementation identifier.
20 **version** is the version of the interface.
pData is data passed from caller and/or registry.
pInterceptionData is a pointer to interception data.
pl is a pointer to plugin instance handles.

25 [0126] The **_ec_pif_instantiate()** function, given a pointer to an <interface
id>, version of the interface and a pointer to an <impl id>, instantiates a plugin
implementing the interface being realized and returns a set of handles about the
plugin and the instance of the plugin being instantiated in a memory block
pointed to by **pl**. The **version** specifies the version of the interface whose
30 <interface id> is pointed to by **pIid**.

[0127] The **pInterceptionData** points to a in-core data structure of data type struct **e_pif_interception_data** defined as follows :

```
5  struct e_pif_interception_data {
    struct _e_pif_iversion  m_pif_version ; /* vers of this structure */
    void const * *fanout_interception_seq ; /* ordered sequence of
                                           instance addresses in fanout
                                           type interception sequence */
10  TM32U fanout_interception_seq_len ; /* number of addresses in
                                           the interception sequence */
    void *next_ip ; /* address of plugin instance next (relative to
                    callee) in the stack type interception sequence */
15  }
```

The pointer **pl** points to a memory block of data type struct **e_pif_instance_handles** defined as follows:

```
20  struct _e_pif_instance_handles { struct _e_pif_iversion m_pif_version
    ; /* version of this structure */
    void *pVtbl ; /* address of plugin Vtbl */
    void *pPrivData ; /* address of private data */
    struct _e_pif_plugin_info *pPluginInfo ; /* plugin info */
25  } ;
```

[0128] In the **pInterceptionData** structure the **pVtbl** contains the address of the Vtbl of the plugin being instantiated. The **pPrivData** contains the address of the private data of the instance of the plugin being created. **pPluginInfo** contains the address of the memory block of type struct **_e_pif_plugin_info**, containing plugin information specific to the plugin being instantiated. It is the responsibility of the plugin to populate the fields of this structure. The struct **_e_pif_plugin_info** is declared as follows:

typedef struct _e_pif_plugin_info {
struct _e_pif_iverison m_pif_version ; /* version of the Plugin
Framework */
5 struct _e_pif_iverison m_i_version ; /* version of the interface
implemented by the plugin */
char * m_impl_id ; /* interface implementation id */
char * m_interface_id ; /* interface id */
int m_Vtbl_size ; /* size of Vtbl in terms of number of entries */
10 char * m_vendor ; /* vendor name */
char * m_productname ; /* product name */
char * m_vendorversion ; /* vendor assigned version number */
TM32U m_flags ; /* flags */
/* addresses of PIF imposed functions */
15 TM32I (*destroy) (_TCADEF, const struct
_e_pif_instance_handles *, TM32U) ; /* function called by the PIF
to destroy the plugin */
TM32I (*copy) (_TCADEF, const struct _e_pif_interception_data *,
struct _e_pif_instance_handles *, TM32U) ; /* function called
by the PIF to copy the plugin's private data */
20 } _e_pif_plugin_info, *p_e_pif_plugin_info;

[0129] The _e_pif_plugin_info structure contains information relevant to
the implementation of the interface. The m_flags field defines flags set by the
implementation and interpreted by the PIF. In one embodiment of the invention,
25 the following flags are defined:

EF_PIF_SINGLETON -- signal or flag that the implementation is a
singleton object

EF_PIF_STACK -- signal that the implementation is a stack-type
intercepting plugin

30 **EF_PIF_FANOUT** -- signal that the implementation is a Fanout type
intercepting plugin

EF_PIF_CONCURRENCYAWARE -- signal that the implementation
(whether it is a derived implementation or a head of a Fanout or STACK type
interception sequence) is concurrency aware

[0130] The EF_PIF_SINGLETON flag is a hint to the Plugin Framework to indicate whether the implementation is a singleton. When a singleton implementation is instantiated, new calls to instantiate the implementation result in a reference to the first plugin instance. The PIF can use this hint to optimize reference handling for other _e_pif_realize() calls to this implementation (in that the Plugin Framework is not required to call the _ec_pif_instantiate() function).

[0131] The flags specified by m_flags field are not mutually exclusive. EF_PIF_QUERY is one example of such a flag. When it is set, _ec_pif_instantiate() populates pVtbl and pPluginInfo fields of struct _e_pif_instance_handles pointed to by pl without instantiating the plugin.

_e_pif_realize

The _e_pif_realize function realizes an interface:

```
15 _e_pif_realize ( IN _TCADEF,  
IN    const char    *pIID,          /* pointer to interface id */  
      const char    *pImplId,      /* pointer to implementation id */  
IN    const struct _e_pif_iversion *version, /*interface version */  
IN    const void *data, /* data passed to plugin from the caller */  
20 IN    long    datalen,          /* size of buffer data points to */  
OUT   void        **pI,          /* interface pointer */  
IN    TM32U        flags /* flags */  
);
```

[0132] The _e_pif_realize function realizes an interface specified by plIID and version by instantiating the interface implementation specified by plImplId. The client of an interface should have a pointer to newly created instantiation of a plugin backing the interface before it invokes any function of the interface. It acquires this handle for the interface by invoking the _e_pif_realize function.

[0133] The plImplId is either the <impl id> of or a <selector> for the plugin to be instantiated.

[0134] If **plmplld** is specified as NULL, then the default implementation (DefaultImpl) for the interface <interface id> is loaded to back the interface. If no default implementation for the interface is set, then a registered implementation with the equal major version number to that of the interface (being realized) and the highest minor version number is loaded to back the interface subject to the version control rules specified below:

[0135] The major version number of the target plugin should match the major version number of the interface. Otherwise, the interface being realized and the target implementation are not compatible.

[0136] The minor version number of the target plugin should be equal to or higher than that of the interface being realized. Otherwise, the interface and the target implementation may not be compatible.

[0137] If the target implementation is inheriting from other plugins, all of the plugins in the inheritance sequence should have a major version number equal to that of the interface being realized.

[0138] If the target implementation is inheriting from other plugins, at least one of the plugins in the inheritance sequence should have a minor version number that is equal to or higher than that of the interface being realized.

[0139] If **plmplld** is specified and **EF_PIF_EXACT_MATCH** flag is set, then the plugin specified by **plmplld** is loaded subject to version control rules as specified above. If it is not registered (i.e., not found), then this function fails and returns an **EE_PIF_NOT_REGISTERED** error value is returned.

[0140] If **plmplld** is specified, but not registered or found, and the **EF_PIF_EXACT_MATCH** flag is not set, then the system attempts to locate the default implementation for the interface. If the default implementation is not compatible or not found, then the system will attempt to locate a compatible implementation with the highest minor version equal to or greater than the value

specified in the `version` argument. If a compatible implementation does not exist, then the function fails, returning an `EE_PIF_NOT_REGISTERED` error. The specified plugin is then located according to the search rules associated with the registry such as, for example, first the client's (caller's) profile and then the system-wide profile for the interface ids.

[0141] The **data** point to data passed to the plugin from the caller, and **datalen** specifies the length of the buffer pointed to by **data**.

_e_pif_dupref

The **_e_pif_dupref** function increments the reference count associated with a loaded plugin instance or duplicates a plugin instance:

```
_e_pif_dupref (IN _TCADEF,  
IN void * pl, /* pointer to plugin instance */  
OUT void **ppdup, /* duplicated plugin instance */  
IN TM32U flags /* shallow or deep copy */  
);
```

[0142] The **_e_pif_dupref** increments the reference count of the plugin instance pointed to by **pl** and duplicates the address of the plugin instance into **ppdup**. It should be called for every new copy of a pointer to an instant of a plugin.

[0143] The flag may include **EF_PIF_DEEP_COPY**, which if specified, causes the Plugin Framework to create a duplicate copy of the instance specified by **pl** and return an interface pointer to the duplicate copy into **ppdup**. The duplicate instance has its own memory block for its private data (if such exists), life control and unique interface pointer.

_e_pif_release

The **_e_pif_release** function decrements the reference count associated with a loaded plugin instance:

5 **_e_pif_release**(IN **_TCADEF**,
IN void * **pI**, /* pointer to plugin instance to be released */
IN TM32U **flags** /* flags */
) ;

10

[0144] The **_e_pif_release** decrements the reference count of the plugin instance pointed to by interface pointer **pl**. If the reference count of the specified plugin instance falls to 0, then the plugin instance is destroyed.

15 **_e_pif_iscompatible**

The **_e_pif_iscompatible** function checks if a specified interface version is supported by a plugin instance:

20 **_e_pif_iscompatible** (IN **_TCADEF**,
IN void * **pI**, /* pointer to plugin instance */
IN const struct **_e_pif_iversion** ***version**, /* interface version */
IN TM32U **flags** /* flags */
) ;

25 The **_e_pif_iscompatible** checks to see if the plugin instance specified by **pl** is compatible with the interface version specified by **version**.

_e_pif_interception_seq

30 The **_e_pif_interception_seq** function returns an ordered sequence of addresses of the instances of the plugins in the interception sequence:

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5 _e_pif_interception_seq(IN _TCADEF,
 IN void * pI,
 OUT const struct _e_pif_interception_data**ppInterceptionData,
 /* interception data */
 IN TM32U flags /* flags */
) ;

10 **[0145]** There may be only one plugin in the sequence, Regardless, the
 _e_pif_interception_seq returns the addresses of the instances of the
 intercepting plugins in the calling sequence relative to the plugin instance
 specified by pl into an in-core data structure of data type struct
 _e_pif_interception_data pointed to by *ppInterceptionData.

15 **[0146]** The data structure struct e_pif_interception_data is defined as
 follows:

20 struct e_pif_interception_data {
 struct _e_pif_iversion m_pif_version ; /* version of this structure */
 void **fanout_interception_seq ; /* ordered sequence of instance
 addresses in fanout type interception sequence */
 TM32U fanout_interception_seq_len ; /* number of addresses in the
 interception sequence */
 void **next_ip ; /* address of plugin instance next (relative
 to callee) in the stack type interception sequence */
25 } ;

30 **[0147]** If the caller is a fan-out type plugin, then n ordered sequence of the
 addresses of the **Fanout** intercepting plugin instances which make up the
 interception sequence for the **Fanout** plugin is returned into an array
 ***fanout_interception_seq**. The **fanout_interception_seq_len** variable
 specifies the number of addresses in this array.

[0148] In the case of stack type intercepting plugins, the address of the
 next plugin instance in the calling sequence is returned into ***next_ip**. If the plugin

instance specified by **pl** is the last plugin instance in the interception sequence, then a NULL is returned in ***next_ip**.

_e_pif_this

5 The **_e_pif_this** function is used to return the address of the private data area:

10 _e_pif_this (IN _TCADEF,
 IN void *pI,
 IN const void *pVtbl,
 OUT void **ppriv,
 IN TM32U flags /* flags */
) ;

15 **[0149]** The **_e_pif_this** returns the address of the private data area of the plugin instance specified by **pl**. The **pVtbl** handle points to the plugin specific Vtbl. This is the same Vtbl whose address is returned from **<_ec_pif_instantiate>()** function during the creation of the instance of the plugin.

_e_pif_getinfo

20 The **_e_pif_getinfo** function is used to get information about a loaded plugin:

25 _e_pif_getinfo (IN _TCADEF, IN void * pI,
 OUT TM32U *info_seq_len,
 OUT const _e_pif_plugin_info_public * const **pInfo,
 IN TM32U flags /* flags */
) ;

30 **[0150]** The **_e_pif_getinfo** gets information about a plugin instance specified by **pl**. This information is returned into the **_e_pif_plugin-info-public**

structure pointed to by **plInfo**:

```
typedef struct _e_pif_plugin_info_public {  
    struct _e_pif_iversion  m_pif_version ;    /* version of PIF */  
5    struct _e_pif_iversion  m_i_version ;      /* version of the interface  
    implemented by the plugin */  
    char * m_impl_id ;          /* interface implementation id */  
    char * m_interface_id ;     /* interface id */  
    char * m_vendor ;           /* vendor name */  
10    char * m_productname ;      /* product name */  
    char * m_vendorversion ;    /* vendor assigned version number */  
    TM32U      m_flags ;  
} _e_pif_plugin_info_public, *p_e_pif_plugin_info_public ;
```

15 **[0151]** The **m_flags** field defines flags set by the implementation and interpreted by the PIF, and include EF_PIF_SINGLETON, EF_PIF_STACK, EF_PIF_FANOUT, and EF_PIF_CONCURRENCYAWARE, all of which are described in further detail above. Concurrency awareness always imply composite behavior -- if the plugin is a derived plugin or a head of an interception sequence, then this means that all of the plugins involved in the composition are concurrency aware and that if one of the components does not support concurrency, then the composition is not concurrency aware. Consequently, in this case the concurrency aware flag is not returned.

20 **[0152]** The **flags** argument specifies optional flags, for example the EF_PIF_DETAILEDINFO flag. If it is specified, **_e_pif_getinfo()** returns detailed information about the plugin specified. If the plugin specified is a derived implementation, then the information about all the implementations involving in the derivation of the plugin are returned, starting from the most derived implementation. If the plugin specified is the head of a Fanout type or STACK type interception sequence, then the information about all the plugins involved in
25
30 the interception sequence is returned, starting from the plugin specified (head of

interception sequence) followed by the intercepting plugins, left-to-right in case of Fanout type, and top-down in case of STACK type.

_ec_pif_destroy

5 The **_ec_pif_destroy** function is used to destroy a plugin instance:

```
10       _ec_pif_destroy ( IN _TCADEF,  
          INOUT struct _e_pf_instance_handles *pIhandles, /* instance cookies  
          */  
          IN TM32U       flags               /* flags */  
          ) ;
```

15 **[0153]** The **_ec_pif_destroy** releases the plugin instance specific system resources specified by **plhandles**. The **plhandles** points to a memory block of data type struct **_e_pif_instance_handles** defined as follows:

```
20       struct _e_pif_instance_handles {  
          struct _e_pif_iversion m_pif_version ;   /*    version of this  
          structure */  
          void           *pVtbl ;               /* address of plugin Vtbl */  
          void           *pPrivData ; /* address of plugin instance specific  
          private data */  
          struct _e_pif_plugin_info       *pPluginInfo ;   /* plugin info */  
          } ;
```

25 wherein the pVtbl contains the address of the Vtbl of the plugin instance, and pPrivData contains the address of the private data of the plugin instance being destroyed. If no private data is used by the plugin instance, then the value of pPrivData is set to NULL. pPluginInfo contains the address of the memory block
30 of type struct **_e_pif_plugin_info**, containing plugin information specific to the plugin instance. This function is only invoked by PIF when the reference count associated with a plugin instance falls to 0.

_ec_pif_copy

The **_ec_pif_copy** function creates a duplicate copy of a plugin instance:

```
5  _ec_pif_copy ( IN _TCADEF,  
    IN  const struct _e_pif_interception_data *pInterceptionData, /*  
    interception data */  
    INOUT struct _e_pif_instance_handles      *pIhandles, /* instance  
    cookies */  
    IN TM32U  flags      /* flags */  
10 ) ;
```

The **_ec_pif_copy** creates a duplicate copy of plugin instance private data specified by **plhandles** and returns pointers to duplicate copies in the data structure pointed by **plhandles**.

15 **[0154]** The **pInterceptionData** points to an in-core data structure of data type struct **e_pif_interception_data** (defined above), while the **plhandles** points to a memory block of data type struct **_e_pif_instance_handles** (also defined above).

20 **[0155]** The **pVtbl** is a pointer containing the address of the **Vtbl** of the plugin instance whose private data are being duplicated. **pPrivData** is a pointer containing the address of the plugin instance private data. If no private data are used by the plugin instance, then **NULL** is returned. The **pPluginInfo** pointer contains the address of the memory block of type struct **_e_pif_plugin_info**, containing plugin instance specific information which is declared as follows:

```
25 typedef struct _e_pif_plugin_info {  
  
    struct _e_pif_iversion  m_pif_version ;    /* version of the Plugin  
    Framework */  
30    struct _e_pif_iversion  m_i_version ;      /* version of the interface  
    implemented by the plugin */  
    char * m_impl_id ;      /* interface implementation id */  
    char * m_interface_id ;  /* interface id */
```

```

int    m_Vtbl_size ;           /* size of Vtbl in terms of number of
entries */
char   * m_vendor ;           /* vendor name */
char   * m_productname ;      /* product name */
5 char   * m_vendorversion ;   /* vendor assigned version number */
TM32U m_flags;                /* flags */

/* addresses of PIF imposed functions */

10 TM32I (*destroy) (_TCADEF, const struct _e_pif_instance_handles *,
TM32U) ; /* function called by the PIF to destroy the plugin */
TM32I (*copy) (_TCADEF, const struct _e_pif_interception_data *,
struct _e_pif_instance_handles *, TM32U) ; /* function called by the
PIF to copy the plugin's private data */

15 } _e_pif_plugin_info, *p_e_pif_plugin_info;

```

[0156] The `_e_pif_plugin_info` structure contains information relevant to the implementation of the interface. The `m_flags` field defines flags set by the implementation and interpreted by the PIF. Flags may include `EF_PIF_SINGLETON`, `EF_PIF_STACK`, `EF_PIF_FANOUT`, and `EF_PIF_CONCURRENCYAWARE` /*, all of which are described in further detail above.

25 **epifreg**

The `epifreg` function or command registers a plugin implementation, and uses the following syntax:

```

30 epifreg -p implid -i interfaceid -v Major.Minor -f imagePath \
[-e entryFunction] [-b baseImplid] [-o profileId]
[-u userParameters] \
[-s InterceptorType[:implid1,...,implidN]]

```

[0157] The epifreg function can take a variety of options as indicated above, wherein the options have the following meaning:

-p Implementation identifier of the plugin to be registered. An implementation identifier is a unique value that has the following syntax:
5 <implid> ::= <component name> [/<sub-component name>]/<implementation name>.

-i Identifier of the interface implemented by the plugin. An interface identifier is a unique value that has the following syntax: <interfaceid> ::= <component name> [/<sub-component name>]/<interface name>. If the interface does not
10 exist in the registry then, it is automatically created.

-v Version number of the interface implemented by the plugin. A version number is composed of a major version number and a minor version number.

-f Path name of the container or dynamic loadable library (DLL) containing the plugin implementation.

15 -e Name of the function implementing the _ec_pif_instantiate () routine. This function is used by the Plugin Framework to instantiate the plugin. If this option is not specified, the Plugin Framework will use the default _ec_pif_instantiate () routine.

-b This option is used to specify that this plugin uses implementation
20 inheritance.

-o This option is used to add the plugin to the specified profile. If the profileid does not exist, a new profile is created. Profiles can be associated with a processes by setting the EV_PIF_PROFILE environment variable to a profile identifier. The Plugin Framework always searches the plugin information in the
25 specified profile before it searches the default system-wide profile "SYSTEM".

-u User parameters (for example, a string of characters) to be passed to the implementation of a plugin during its instantiation.

-s This option is used to specify that the plugin is an interceptor. The interceptorType argument refers to the type of interception implemented by the plugin and its value can either be STACK or Fanout. Optionally, an interception sequence can also be specified after the ':' character. This interception sequence is a comma-separated list of implementation identifiers that specifies the intercepting plugins and the interception order.

epifunreg

The epifunreg function unregisters a plugin:

```
epifunreg -p implid [-o profileId]
```

[0158] The epifunreg command unregisters the specified plugin. The -p option specifies the implementation identifier of the plugin to be unregistered. If this option is used alone then, the plugin's data stored in the Plugin Framework is unregistered (including the data stored in all of the existing profiles). The -o option can be optionally used to specify that the information about the plugin should be removed from the specified profileId. This command does not remove the data about the related plugin's interface, which can be removed with the epifregedt command.

epifregedt

The epifregedt function edits the attributes of implementations, interfaces, and profiles stored in the Plugin Framework registry:

```
epifregedt [-g | -s | -d | -c | -m] -k Key [-a AttrName[=AttrValue]
```

The epifregedt command edits the attributes of a PIF registry object specified with the -k option. Registry objects are uniquely identified within the registry with their corresponding Key. The Key of a PIF registry object has the following syntax:

5

```
<ProfileId> [/impl|interfaces/<ObjId>]
```

wherein:

<ProfileId> is the profile id of the profile the object is registered in.

10

impl specifies that the object is an implementation object.

interfaces specifies that the object is an implementation object.

<ObjId> specifies an interface object id (InterfaceId) or an implementation object id (ImplId).

15

[0159] The Plugin Framework searches the specified profile in the registry for the specified interface and/or implementation object data. The <ProfileId> or <ObjId> can be specified as "" to indicate that the edit operation applies to all existing profiles or interface/implementation ids, respectively. "SYSTEM" is the <Profile id> for the default system-wide profile.

20

[0160] The -a option is used to specify the attributes involved in the editing operation on the specified object. The AttrName is the name of an attribute of the edited object and AttrValue is the value assigned to this attribute. Some attributes can be used to narrow the scope of the particular editing operation (such as a set, create, or delete).

25

The following options specify the editing operation performed by the epifregedt command:

-g Get the values of the selected attributes of the specified object. If no attributes are specified with the -a option then, all attributes of the object are

retrieved. Otherwise, only the specified attributes are retrieved. With this and all the other options, if AttrValue is supplied, it is specified, then it is used to narrow the scope of this operation. In the case of multiple AttrName attributes with the corresponding AttrValue values are specified, then only the objects with the identical AttrValue values for the corresponding AttrName attributes are retrieved.

-s Set, create, or change the values of the selected attributes of the specified object. Some attributes are required when a new object is created in the registry. These attributes are specified with the -a option.

-d Delete the selected attributes of this specified object. If no attributes are specified with the -a option then, the object and all its attributes are removed from the registry. Otherwise, only the specified attributes are deleted.

-c Copy the specified object to another profile. The new profile should be specified with the -a option using the ProfileId as the value for AttrName and the new profile identifier as the value of AttrValue.

-m Move the specified object to another profile. The new profile should be specified with the -a option using the ProfileId as the value for AttrName and the new profile identifier as the value of AttrValue. If the target profile does not exist then, a new profile is created.

Example Implementation

[0161] This section provides a sample code illustration demonstrating how to construct a PIF compliant client application and a corresponding plugin. The following files are shown merely for demonstration purposes to better illustrate the invention. It will be evident to one skilled in the art that the procedures used may be extended to apply to more complex situations and applications, and that the invention is not limited to the C language examples give below.

[0162] The plugin can be defined in a metalanguage format using a plugin wizard or similar tool. The metalanguage defines the plugin operations, and also such variables as the plugin name, the interface name, and the interface version number.

5

Plugin Description File

[0163] The following plugin description file (dummy.pi) is an example of a description file used to define a plugin. The plugin description may, in some embodiments, be created by a plugin wizard or plugin design tool. At a minimum it should contain a plugin name (in this case "dummy"), an interface name ("sec"), and an interface version number ("1.2"). The plugin should also contain a number of operations (in this example denoted as op 1, op 2, op 3, and op 4. The operations define the functions the plugin will actually provide to the calling application.

10

15

```
===== dummy.pi =====
@plugin dummy
@interface sec
@interface_version 1_2
@operations
void op1(int i, double k)
int op2(void *foo)
void *op3(const char *x)
char * op4()
@end
```

20

25

Plugin Header File

[0164] The dummy.h file below is an example of a generated include or header file which is output by the plugin wizard. The header file must be included at compile time into each plugin implementation and client application. The

30

include file provides a specification of the particular interface in which the plugin operates.

5 ===== dummy.h =====
#ifndef dummy_h
#define dummy_h

#include "e_eng_pif.h"
struct sec_1_2 ;
10 typedef struct sec_1_2_Vtbl {
void (*op1) (struct sec_1_2 *, int i, double k);
int (*op2) (struct sec_1_2 *, void *foo);
void* (*op3) (struct sec_1_2 const char *x);
char * (*op4) (struct sec_1_2 *);
15 } sec_1_2, *sec_1_2_ptr ;
#define sec_1_2_op1(ip, _a1, _a2) \
(ip->op1(ip, (_a1), (_a2)))
#define sec_1_2_op2(ip, _a1) \
(ip->op2(ip, (_a1)))
20 #define sec_1_2_op3(ip, _a1) \
(ip->op3(ip, (_a1)))
#define sec_1_2_op4(ip) \
(ip->op4(ip))
#endif /* dummy_h */
25

[0165] In this example, the include file includes a name ("dummy"), and a data structure definition that defines the data structure for the particular interface and version number (in this case sec. 1.2). The data structure includes pointers for all of the operations supported by this particular interface and version number.

Plugin Application File

[0166] The dummy.c file below is an example of the generated skeleton template, and represents the actual plugin application. The only modifications from the generated .h file is the replacement of the generated comments in each of the operation implementations with actual code, and the addition of private

data members to the Private data structure. The c file when compiled is used to provide the actual plugin implementation. Certain verbs (such as pif-destroy and pif-copy) are required in order for the interface to handshake successfully with a calling application. Other verbs (op1, op2, op3, op4) provide the functional operations of the plugin framework.

5

```
===== dummy.c =====
#include "dummy.h"
#include <malloc.h>
10 #include <string.h>
#include "e_eng_pif.h"
typedef struct {
    .....
} Privatesec_1_2, *Privatesec_1_2_ptr;
15 int
sec_1_2_ec_pif_destroy_impl(const struct _e_pif_instance_handles *pI)
{
    ....

20     if (pI->pPrivData != NULL)
free(pI->pPrivData );
}

int
25 sec_1_2_ec_pif_copy_impl(const struct _e_pif_interception_data
*pInterceptionData, struct _e_pif_instance_handles *pI){
    .....
}

30 static void
sec_1_2_op1_impl(struct sec_1_2 *ip , int i, double k)
{
    .....
}

35 static int
sec_1_2_op2_impl(struct sec_1_2 *ip , void *foo)
{
    .....
}
```

```

}

static void *
sec_1_2_op3_impl(struct sec_1_2 *ip , const char *x)
5 {
    .....
}

static char *
10 sec_1_2_op4_impl(struct sec_1_2 *ip)
{
    .....
}

15 static const _e_pif_plugin_info sec_1_2_plugin_info = {
/* m_pif_version.i_major_version */ 1,
/* m_pif_version.i_minor_version */ 0,
/* m_i_version.i_major_version */ 1,
20 /* m_i_version.i_minor_version */ 2,
/* m_impl_id */ "sec1",
/* m_interface_id */ "sec",
/* m_vtbl_size */ 4,
/* m_flags */ 0,

25 /* Plugin Vendor Info */
/* m_vendor */ "RSA",
/* m_productname */ "Roadrunner Exterminator",
/* m_vendorversion */ "2000",

30

/* PIF imposed functions */
sec_1_2_ec_pif_destroy_impl,
sec_1_2_ec_pif_copy_impl,
35 };

static sec_1_2_vtbl Vtblsec_1_2 = {
40 sec_1_2_op1_impl,
sec_1_2_op2_impl,
sec_1_2_op3_impl,
sec_1_2_op4_impl,

```

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};

5 #ifdef __cplusplus
 extern "C"
 #endif
 #ifdef WIN32
 __declspec(dllexport)
 #endif

10 int
 sec_1_2_instantiate(
 IN const char *pIID, /* pointer to interface id
 IN const char *pImplId, /* pointer to implementation id */
 IN struct _e_pif_iversion *version, /* interface version */
15 IN const struct _e_pif_data *pData /* data passed from
 caller and/or registry */
 IN const struct _e_pif_interception_data *pInterceptionData,
 /* interception data */
 INOUT struct _e_pif_instance_handles *pI, /* pointer to
20 instance of plugin
 IN TM32U flags /* flags */
)
 {
 Privatesec_1_2_ptr priv;
25

 if (flags & EF_PIF_QUERY) {
 pI->pPluginInfo = & sec_1_2_plugin_info ;
 }
30 else {
 priv = (Privatesec_1_2_ptr) calloc(1, sizeof *priv);
 if (! priv) {
 return EE_PIF_NORESOURCE ;
 }
35 pI->pVtbl = &Vtblsec_1_2 ;
 pI->pPrivData = priv ;
 pI->pPluginInfo = & sec_1_2_plugin_info ;
 }

40
 return ;
 }

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Application File

[0167] The test.c file shown below is an example of a client application that loads and invokes operations on the plugin. The client application is written so as to call the required interface definitions (specified in dummy.h). The client application must successfully realize the desired interface (sec) with the specified plugin. Thereafter it uses a pointer (pin) to refer to an implementation vtable (Vtbl). The operations themselves are called through a series of put commands.

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```
10  ===== test.c =====
    #include <stdio.h>
    #include "e_eng_pif.h"
    #include "dummy.h"
    main()
15  {
        struct sec_1_2 *pin;
        struct _e_pif_iversion version;
        version.i_major_version = 1 ;
        version.i_minor_version = 2 ;
20     if (_e_pif_realize("sec", "sec1", &version, NULL, NULL, &pin,
        NULL, 0) != EE_PIF_SUCCESS) {
            puts("can't realize interface with the specified plugin");
            exit(1);
        }
25     puts(">>> Calling op4");
        puts(sec_1_2_op4(pin));
        puts(">>> Calling op3");
        puts((char *) sec_1_2_op3(pin, "hello world!"));
        puts(">>> Calling op4");
30     puts(sec_1_2_op4(pin));
        _e_pif_release(pin);
        .....
    }
```

[0168] The client does not need to specify an actual implementation (although it does in this example). When an implementation is not specified the client is given the default implementation for that interface.

5 Function Design Specification

[0169] In this section, an example of a design for the function-by-function realization of an interface process supporting both (a) implementation inheritance and (b) no implementation inheritance cases is presented. The example design supports interface inheritance even though it may not be a requirement for all embodiments of the engine. The key aspects of this particular design are as follows:

The client is presented a realized interface as a C struct, of which the member variables are the pointers to functions of an implementation that are implementing the function signatures of the interface, regardless of whether the implementation backing the interface is a single implementation, or a derived implementation. The client is not aware of whether the realized interface is an original interface or a composite or inherited interface, and instead sees it as a single interface.

[0170] The interface method invocations pass an interface pointer to the plugin instance as the first argument.

[0171] The implementation methods may access per instance private data by invoking an `_e_pif_this()` function provided by the PIF.

[0172] The realization and implementation process of this particular design embodiment is shown in **Figure 12**. As shown in Figure 12, the process includes a realization phase, interceptor phase, load and unload phases, and a rehears phase. These are discussed in further detail below.

_e_pif_realize() 390

[0173] The e_pif_realize function 390 calls pif_init to initialize a mutual exclusion lock routine (mutex). A mutex is an abstract structure that enforces a policy of mutual exclusion. Traditionally, only one process thread at a time may hold a particular mutex, and threads trying to lock a held mutex will block until the mutex is unlocked. Mutexes must be exited in the opposite order in which they were entered, and that they cannot be reentered before exiting.

[0174] If the registry plugin is not already realized, then the process will attempt to realize it. This instance of the registry plugin can be cached for performance benefits. The count of active plugin's is incremented to reflect the new plugin and the mutex is then unlocked.

[0175] Since the process does not know when the framework will no longer be needed it keeps track of how many plugin instances are active at any given time. Whenever this count drops to zero the cached registry plugin is released. The use of cache for optimization is only useful when there will be at least one active plugin instance when other plugins are being realized. If the design model is such that only one plugin is ever active at a time, then the registry plugin will be realized and released each time. A side effect of caching the registry plugin is that the underlying registry being used does not see registry changes until the registry is closed and re-opened.

[0176] The process then calls the realize_frontend function 392. If this is not successful then the mutex is locked the active plugin count is decremented. If the active count goes to zero then the registry plugin is released, and the mutex unlocked.

realize_frontend() 392

[0177] The process continues with a realize_frontend function 392 which as a first step constructs a PIF_RARGS stack using supplied arguments and

calls realize_internal 394. If realize_internal finds a singleton plugin value then the corresponding singleton is returned. If realize_internal finds a stack interceptor then the handle or pointer of the first plugin in the stack is returned. If realize_internal returns anything else but SUCCESS then an error is returned.

5 If none of the above criteria are met, the plugin is constructed from its components. The realize_frontend function loops through each implementation and verifies the major version number, while at the same time looking for both the highest minor version number and the largest Vtbl size.

10 **[0178]** A verification step ensures that the highest minor version number is greater than or equal to that requested. The size block of memory required is computed and allocated. One block of memory is allocated for the variable sized PIF_CONTROL block, the Proxy Vtbl, the fan-out interceptor array, and the array of info_public pointers.

15 **[0179]** The PIF_CONTROL block is filled in, as is the Proxy Vtbl by looping through each implementation's Vtbl, and filling in empty entries in the Proxy Vtbl with non-nil entries from the Vtbls.

[0180] The the filled-in Proxy Vtbl is checked for empty entries, and if any are found, a NORESOURCE error is returned.

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realize_internal() 394

25 **[0181]** One of the additional arguments is an array of the PIF_PINFO data structure that is declared as a local. This array is used so all the implementations making up the complete plugin can be instantiated first so that the realization process knows how big a chunk of dynamic memory to allocate. This is dependent on both the depth of implementation inheritance, and on the size of the largest Vtbl within all the implementations that make up the complete plugin. Because this array is allocated before the process knows the actual depth of

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implementation inheritance the framework may impose an implementation restriction on the maximum depth of implementation inheritance allowed. If during the realization process this limit is reached the process will fail and an returned.

5 **[0182]** If no implementation identifier is specified then the first read of the registry is to call GetIntf 400 using the specified interface identifier and major version number of the interface. If the DefaultImpl attribute is non-null then it is used as the implementation identifier.

10 **[0183]** If no implementation identifier is specified and the DefaultImpl attribute mentioned above is nil then the HighestMinorImpl attribute is looked at.

15 **[0184]** If an implementation identifier is specified, or one is determined from the above steps, the next step is to see if the identifier is a selector or alias by calling GetAlias 400. If no match is found then the implementation identifier is not an alias. If a match is found then what is now known to be an alias is used as an attribute name and it's value is read from the registry. The value of this attribute is then used as the implementation identifier, but is first checked recursively to see if the alias mapped to another alias.

20 **[0185]** Using the interface identifier argument and the resultant implementation identifier a list of singleton plugins that have already been realized (and have not yet been released) is checked for one whose most derived implementation's info structure has the appropriate m_interface_id and m_impl_id fields. If a match is found then _pe_pf_dupref is called on the matching plugin and the new pointer is returned. The search for an existing matching singleton is not done when the implementation being instantiated as a base implementation.

25 **[0186]** Using the resultant implementation identifier GetImpl 400 is called. If the implementation does not exist, an error is returned, unless the identifier

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used is the one originally specified by the caller, in which case the process starts at the top as if the caller had not specified an implementation identifier.

[0187] The realize_internal next checks the InterceptionType attribute. If this attribute indicates anything other than "NoInterceptor" then it calls an internal routine that handles the realization of an interceptor. This step is skipped if the implementation being realized is one that was specified in a stack Interception Sequence.

[0188] If the InterceptionType attribute is set then the process calls realize_interceptor 402.

[0189] If the InterceptionType is STACK then a pointer is also set to the next stack member.

[0190] The _e_dl_load function is called using either the ImagePath attribute or the implId.

[0191] The _e_dl_getfuncaddr function 398 is called using either the EntryFunc attribute or the default "_ep_dl_instantiate". The plugin's _ep_dl_instantiate function is then called.

[0192] The appropriate info_public structure (m_pinfo in the PIF_PINFO struct) is initialized from the corresponding implementations private info structure.

_e_dl_unload () 404

[0193] The value of the ImagePath attribute is passed to _gp_dl_load. Then the value of the EntryFunc attribute is passed to _gp_dl_getfuncaddr 398 to get the address of the plugin's instantiation routine. The instantiation routine is called with the appropriate arguments that come from those passed in to _pe_pf_realize and internally generated.

[0194] The realize_internal checks the InheritsFrom attribute. If this attribute exists then it calls realize_internal recursively with the value of the said attribute. The implementation identifier specified in the InheritsFrom attribute

when realized by the framework is realized as if the **EF_PF_EXACT_MATCH** flag was specified.

[0195] Once control is returned to `_pe_pf_realize` from `realize_internal` then the size of the Proxy Vtbl needed is determined, and the depth of inheritance is known.

[0196] At this time the system can now check to make sure that there exists at least one implementation making up the complete plugin that implements at least the minimum minor version number requested by the caller. This check is made by looking at each implementation's `_e_pf_plugin_info` data structure. If this check fails then a version mismatch error is returned.

[0197] A `PIF_CONTROL` data structure can now be allocated. The stack local array of `PIF_PINFO` data structures is copied to the `m_pi` field.

[0198] The Proxy Vtbl is now also filled in. Starting with the most derived implementation and ending with the least derived implementation the following is done. For every non-nil entry in the implementations static Vtbl for which there is a nil pointer at the same offset in the Proxy Vtbl, the pointer from the implementations static Vtbl is copied to the Proxy Vtbl.

[0199] The Proxy Vtbl is checked to make sure there are no nil pointers. If any are found, then everything is released and an error returned.

[0200] The `m_publicinfo` field of every member of the `m_pi` field of the `PIF_CONTROL` structure can be initialized by simply copying the corresponding fields from each corresponding implementation's private "info" structure. The vector of pointers pointed to by the `m_publicinfo` field of the `PIF_CONTROL` structure is initialized to point to the appropriate `m_publicinfo` fields in the array of `PIF_PINFO` structures (`m_pi`).

[0201] Each implementation's info data structure is checked to see if the `m_singleton` flag is set. If every implementation has this flag set then the `PIF_SINGLETON` flag in the `PIF_CONTROL` structure is set. If this flag is set

then the PIF_CONTROL structure is linked into a linked list of singleton plugins using the m_nextSingleton pointer.

realize_interceptor() 402

5 **[0202]** Clients or calling applications (callers) make calls to realize_frontend on each implId in the sequence with rdepth+1 and the EXACT_MATCH and IGNORE_ISEQ flags.

10 **[0203]** The returned pointer ip is stored in the PIF_RARGS structure. If it is a Fan-out interception type then fanoutLen (PIF_RARGS) is set to the sequence length. For both interception types the implementation identifiers specified in the InterceptionSeq attribute when realized by the framework are realized as if the **EF_PF_EXACT_MATCH** flag was specified.

15 **[0204]** For a **FAN-OUT** type of interceptor the realize_internal function is called N times with the same arguments as the original call to _pe_pf_realize except for the implementation identifier argument which is replaced with the corresponding one from the sequence. N is the number of implementation identifiers in the sequence. The realize_internal function is then called again, this time with a sequence of pointers to the realized intercepting plugins.

20 **[0205]** For a **STACK** type of interceptor the realize_internal function is also called N times with the same arguments as the original call to _pe_pf_realize. This time the sequence of implementation identifiers is traversed backwards. Additionally, on each call to realize_internal, except the first, a single pointer to the last intercepting plugin realized is passed. If the ImagePath registry attribute exists on the registry key that defined the interceptor sequence, the key is treated as if it were the first plugin in the stacked interception sequence.

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_e_pif_dupref() 406

[0206] In the non-deep copy case the reference count stored in the PIF_CONTROL data structure is simply incremented and the same pointer returned.

5 [0207] In the deep copy case the following is done: A new PIF_CONTROL data structure is allocated.

[0208] If the PIF_STACKI flag is set then _pe_pf_dupref 406 is called on the next plugin in the stack. The new pointer returned is saved in the m_interceptors field of the new PIF_CONTROL data structure allocated. The recursion is done first because the pointer to the next plugin in the new stack is needed before any of the copy routines for any of the implementations for the current plugin are called.

10 [0209] If the PIF_FANOUTI flag is set then _e_pf_dupref 406 is called on each of the plugins in the fan-out interception sequence and the returned pointers stored in the corresponding fields of the new PIF_CONTROL data structure. This recursion is done first because the new sequence is needed before any of the copy routines for any of the implementations for the current plugin are called.

15 [0210] The new PIF_CONTROL data structure is populated from the original PIF_CONTROL data structure, and the reference count of the new PIF_CONTROL set to 1. Using the new PIF_CONTROL data structure the plugin's copy routine (pointed to by its _e_pf_plugin_info data structure) is called. In the case of implementation inheritance each plugin in the inheritance list has its copy routine called.

25 **_e_pif_release() 396**

[0211] The reference count in the PIF_CONTROL data structure is decremented, and if the count after being decremented is greater than zero (0) then it simply returns.

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[0212] The first thing that is done when the reference count goes to 0 is to call the plugin's destroy routine so it can release any of it's resources. In the case of implementation inheritance the destroy routine of the most derived implementations are called first.

5 **[0213]** If the plugin being released is part of a stacked interceptor chain then `_pe_pf_release` is called recursively on the next plugin in the chain.

[0214] If the plugin being released is a fan-out plugin, then each of the corresponding intercepting plugin's is released.

10 **[0215]** If the `PIF_SINGLETON` flag is set in the `PIF_CONTROL` data structure then the linked list of realized singleton plugin's is checked to see if this plugin is on that list, and if so it is removed from that list.

[0216] Finally, the dynamic library handle is unloaded 404, and then the `PIF_CONTROL` data structure freed.

15 **[0217]** When the count of active plugins goes to zero the cached registry plugin reference is released.

[0218] If a release flag is set, then the `_e_pif_release` function is called on the next stack interceptor (if any) and on the sequence of fan-out intercepting plugins.

20 **`_e_pif_this()`**

[0219] The process then simply indexes through the array of `PIF_PINFO`'s in the `PIF_CONTROL` looking for one whose `pVtbl` instance handle matches the passed in key. If a match is found return the corresponding `pPrivData` pointer is returned.

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`_e_pif_interception_seq()`

[0220] A pointer to the `m_interceptors` field in the `PIF_CONTROL` is returned.

_e_pif_getinfo()

[0221] The length and pointer to the array of public info pointers from the PIF_CONTROL is returned.

5 **[0222]** It will be evident to one skilled in the art that while some functions and routines described herein were specified as having certain characteristics, features, and constraints on conforming to certain rules, that these rules need not be adhered to in full or in part in order to operate the invention, and that the examples given are for the purposes of illustrating an embodiment of the invention.

Example Deployment

10 **[0223]** Figure 13 illustrates a flowchart of an example of a method of deploying the invention in a typical client/server environment. As shown in step 370 a set of services is specified by a developer or an administrator for each interface offered by the server. In step 372 implementations are developed for each interface to address the particular service needs of that interface. In step 374 different entities, such as other developers and third-party vendors develop different implementations for that interface, each implementation having a different feature set. In step 376 the calling application or client accesses the server engine and requests a particular implementation type. In step 378, the client makes a call to _e_pif_realize to realize the desired interface. In this process an interface unique identifier is generated and given to the client. The client may then choose (380, depending on its configuration) either a default implementation plugin for this implementation type, or an alternate implementation plugin (for example, the client may specifically request the "AlternateVersion" named implementation). The client receives a handle (which in some cases may be in the form of a token or cookie that the client can store

within the client application itself for future use (382). The handle is used as a pointer into the v table data space populated by the implementation, and hence into the service implementation itself.

5 **[0224]** The foregoing description of preferred embodiments of the present invention has been provided for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise forms disclosed. Obviously, many modifications and variations will be apparent to the practitioner skilled in the art. The embodiments were chosen and described in order to best explain the principles of the invention and its practical application, thereby enabling others skilled in the art to understand the invention for various embodiments and with various modifications that are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the following claims and their equivalence.

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